Environ Monit Assess (2009) 151:327–336
DOI 10.1007/s10661-008-0274-x

Post-classification comparison of land cover using multitemporal Landsat and ASTER imagery: the case of Kahramanmaraş, Turkey

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Received: 12 November 2007 / Accepted: 3 March 2008 / Published online: 9 April 2008

Abstract This study assessed land cover (LC) changes in Kahramanmaraş (K.Maraş) and its environs by using multitemporal Landsat and ASTER imagery, respectively belong to 1989, 2000 and 2004. A priori defined nine land cover classes in the classification scheme were urban and built-up, forest, sparsely vegetated areas, grassland, vegetated stream beds, unvegetated stream beds, bare areas, crop fields, and water bodies. Individual classifications were employed using the combination of both unsupervised and supervised classification methods. Iterative Self Organizing Data Analysis (ISODATA) was used to reduce spectral variation in the scenes arising from complex pattern of crop fields. Maximum Likelihood classifier was used in the LC classification of the individual images. Image pairs of consecutive dates were compared by overlaying the thematic LC maps and cross-tabulating the LC statistics. Urbanization and expansion of agriculture were the major reasons for the dramatic LC conversions. The amount of conversion from crop fields to water occurred as large as 927.67 ha, accounting for 73% of the total land-to-water conversion. Conversions to agriculture have mainly been occurred from grasslands and sparsely vegetated areas as large as 1,314.95 and 1,325.84 ha, respectively. Urban coverage doubled in this period as a result of 1,443.45 ha of increase. Urban area increased in the second period from 2,920 to 3,526 ha. Conversions to agriculture occurred at high amounts. A total of 1,075.79 ha area changed from sparsely vegetated areas to crop fields. A landscape-level environmental monitoring scheme based on satellite remote sensing was proposed for effective environmental resource management.

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Keywords ASTER · Change detection · Environmental monitoring · Kahramanmaraş · Land cover (LC) · Post-classification

Introduction

Land cover (LC) change phenomenon resulting from human interactions in the environment has important implications for sustainable resource use, as it generally reflects degradation or irreversible losses of land and water resources. It mainly arises from diverse and ever-increasing demands for space and resources for settlement, agriculture, tourism, industries and transportation.

Unprecedented changes in the LC, have led to an increased consciousness of its impacts on ecosystems.

Better understanding of these impacts enhances estimating, modeling and forecasting ecosystem dynamics from local to regional levels (Chen et al. 2001). Changes in the LC and land use serve as a robust indicator of land degradation. This change information can be used to examine impacts on landscape structures and functions using simulation models (Weber et al. 2001). Interpretation of land degradation heavily relies on spatial and time scales under consideration (Warren 2002). From this point of view, LC change information at different spatial and time scales can be considered as the basis for evaluating ecosystem conditions and environmental trends. LC changes involve complex sequences. Integration of this complexity into LC change analysis is necessary so as to acquire a better understanding of the causes and the sequence of change and to better predict likely evolutions of LC based on change models (Wang et al. 2006).

The utility of remote sensing and geographic information systems (GIS) in LC mapping and monitoring in terms of evaluating ecosystem conditions have widely been accepted. A broad range of literature includes large-scale analysis of landscapes (Awasthi et al. 2002; Nagendra and Utkarsh 2003), coastal area management (Huang and Fu 2002), urban expansion (Doygun and Alphan 2006; Ji et al. 2001), and vegetation change (Kimoto et al. 2002; Morawitz et al. 2006).

Landscapes in the eastern Mediterranean region of Turkey have recently undergone rapid and extensive LC changes. In this process, agricultural ecosystems were largely occupied by urban areas, while other semi-natural systems were replaced by agriculture (Alphan and Yilmaz 2005). This study aimed to detect LC changes in the vicinity of the city of Kahramanmaraş (K.Maraş) between 1989 and 2004. Post-classification change detection based on multispectral Landsat and ASTER images was employed in order to derive information on current LC changes, which will be favored by decision making process aiming to achieve sustainable resource use.

Study area and the dataset

Study area

The study area covers the city of K.Maraş, Turkey, and its environs, including K.Maraş plain in the south and Ahir Mountain in the North. It is located on the upper part of the eastern Mediterranean region of the country, which is a transition zone between the Mediterranean coast and the Anatolian plateau. Covering a total of 41925.42 ha, the area is bounded by 37°27′33″ and 37°36′57″ northern latitudes and 36°46′25″ and 37°02′55″ eastern longitudes. Location of the area is given in the Fig. 1.

As a result of the geographic location, climate represents characteristics of both temperate Mediterranean and terrestrial climate types. Mean monthly temperature ranges from a maximum of 29.1°C (in August) to a minimum of 5.7°C (in January). Annual precipitation is about 737 mm (TSMS 2007).

The area is located on the convergence of Mediterranean and Irano-Turanian phytogeographical regions. Vegetation cover can be considered in three broad categories in terms of altitudinal zonation: (1) Macchia (500 to 1,200 m); *Quercus coccifera* L., *Styrax officinalis* L., *Olea europea* L. and *Cercis siliquastrum* L., (2) Forest (800 to 1,200 m); *Pinus brutia* Ten., *Pinus nigra* Arnold., *Pinus pinea* L., *Cedrus libani* A. Rich. and *Ostrya carpinifolia* Scop., and (3) Alpine (>2,000 m); *Acantholimon* sp., *Gallium* sp., *Gundelia* sp., and *Papaver* sp. (Korkmaz 2001). Geological structure is mainly characterized by alluvial deposits in the K.Maraş plain, and metamorphic and sedimentary rocks in Ahir Mountain.

Dataset

The dataset comprised satellite images and ancillary data. Multispectral Landsat and ASTER images

Fig. 1 Location of the study area

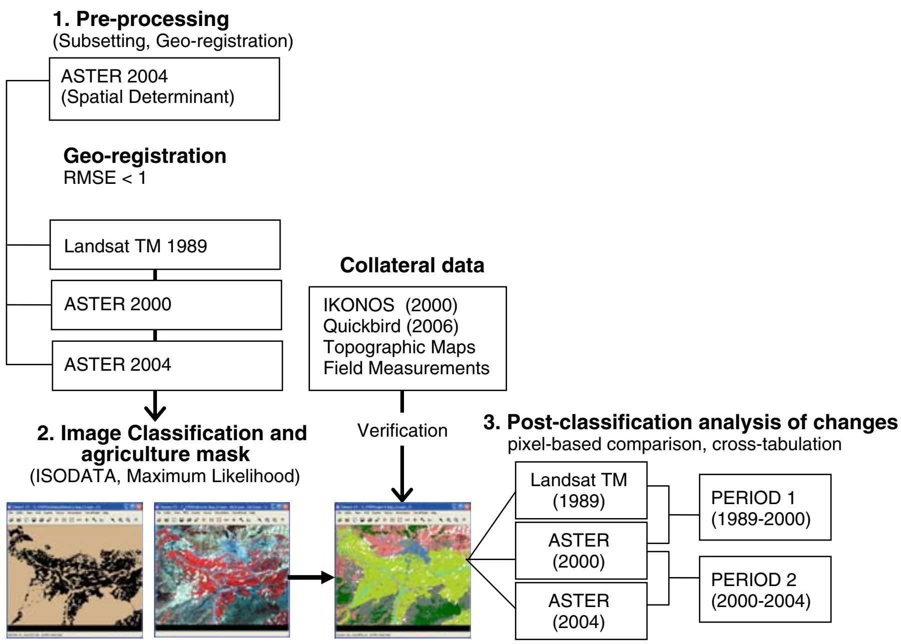

Fig. 2 Principal procedures employed for classification and change detection

belonged to 26 July 1989, 22 June 2000 and 12 September 2004, respectively. Ancillary data layers on the other hand, included 1:25.000 scale topographic maps and high resolution satellite images such as panchromatic Ikonos (1 m) and pan sharpened Quickbird images (0.6 m).

Methodology

Post-classification comparison was done in K.Maraş and its vicinity. Principal procedures of this change analysis were given in the Fig. 2.

The 1989 and the 2000 images were image-to-image georegistered to the 2004 ASTER image using Universal Transverse Mercator (UTM) projection and Nearest Neighbor resampling algorithm.

Two-stage image classification procedures that included unsupervised Iterative Self Organizing Data Analysis (ISODATA) and supervised (Maximum Likelihood) classifications were done. The major aims of this procedure were: (1) to reduce spectral variation in the dataset by identifying crop fields prior to supervised classification and (2) produce thematic LC maps of individual dates. The application of ISODATA by identifying and masking crop fields was given in the Fig. 3.

The ISODATA uses minimum spectral distance to assign a cluster for each candidate pixel. The process begins with a specified number of arbitrary cluster means or the means of existing signatures, and then it processes repetitively, so that those means shift to the means of the clusters in the data (Erdas 1999). On the first iteration of the ISODATA algorithm, the means of *N* clusters can be arbitrarily determined. After each iteration, a new mean for each cluster is calculated, based on the actual spectral locations of the pixels in the cluster, instead of the initial arbitrary calculation. Then, these new means are used for defining clusters in the next iteration. The process continues until there is little change between iterations (Swain 1973). Mask image of crop fields resulting from ISODATA classification of the 1989 image was given in the Fig. 4.

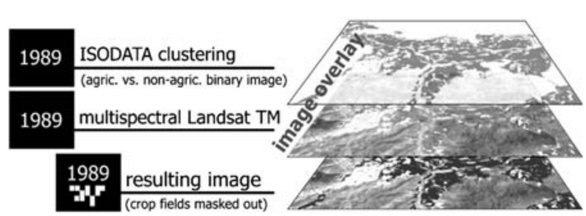

Fig. 3 Application of ISODATA and masking of crop fields for the 1989 Landsat image

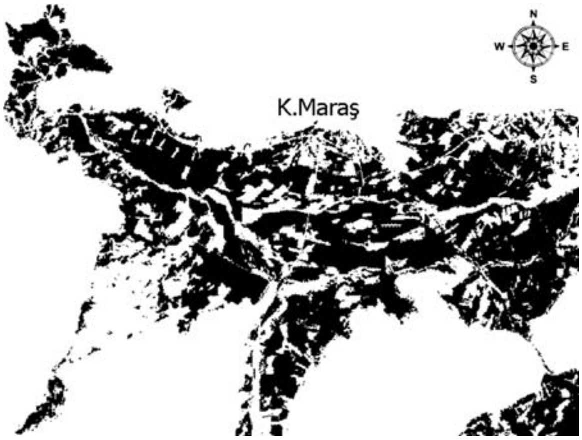

Fig. 4 Mask image of crop fields resulting from ISODATA classification of the 1989 image

Classification scheme

A priori defined nine LC classes in the classification scheme were: (1) urban and built-up areas, (2) forest areas, (3) sparsely vegetated areas, (4) grassland, (5) vegetated stream beds, (6) unvegetated stream beds, (7) bare areas, (8) crop fields, (9) water bodies. Detailed descriptions of these LC categories were given in the Table 1.

Vegetation, built-up features, geology/geomorphology and hydrology are key descriptors to develop a classification scheme for landscape-level environmental mapping and monitoring (e.g. Anderson et al. 1976; CEC 1993; Di Gregorio and Jansen 2000).

Forest areas, sparsely vegetated areas, grassland, crop fields, vegetated stream beds, unvegetated stream beds, and bare areas were described on the basis of vegetation indicator, while the classes urban and built-up and water bodies were described using other indicators such as built-up and hydrology features of the environment, respectively. In the case of vegetation as an environmental indicator, its presence or absence can also be used to describe a LC category. The classes "unvegetated stream beds" and "bare areas" were described on this basis.

Table 1 Classification scheme for the classification and change detection procedures

Indicator	Class name	Description
Built-up features	Urban and built-up	Highly developed building islands in the city core, areas open for residential development at the urban fringe, roads and other built-up or paved-over areas
Vegetation (vegetated/ non-vegetated)	Forest	Afforested areas on southern slopes of the Ahir Mountain, and Pine forests dominating higher altitudes of the hills that confine K.Maraş plain in the South
	Sparsely vegetated areas	Includes both human induced and natural landscapes such as olive groves and Macchia shrubland, mostly observed in the N/NW locations of the study area. Low-canopy cover Pine stands resulted from excessive firewood extraction and grazing were also considered in this class
	Grassland	Vegetated with herbaceous species, low occurrence of shrubs is evident
	Vegetated stream beds	Humid and densely vegetated stream beds. Plant communities dominated by broadleaved tree species such as Caucasian wingnut (*Pterocarya fraxinifolia*), plane tree (*Platanus orientalis*), Laurel willow (*Salix pentandra*), and, in relatively drier locations, kermes oak (*Quercus coccifera*). Poplar plantations (*Populus nigra*) along the streams were also included in this class
	Unvegetated stream beds	Temporarily flooded stream beds with very sparse (e.g. *Tamarix* spp. and *Nerium oleander*) or no vegetation, pebble and gravel pits along the streams, bare areas emerging from decrease of water levels in the dam reservoir
	Bare areas	Areas of very sparse or no vegetation, characterized by outcropping rocks (e.g. limestone). Building construction sites, quarries and other bare surfaces describe this class
	Crop fields	Planted or bare crop fields, excluding vineyards and orchards
Hydrology	Water bodies	Dam reservoir and streams

Results and discussion

Image classifications

Both unsupervised and supervised classifications were used during the analysis of landscape changes. Unsupervised ISODATA classification was used in the first step of the analysis in order to reduce spectral variation in the scenes arising from complex pattern of crop fields.

Application of ISODATA resulted with binary images that include agriculture and non-agriculture classes for each date. Each binary image was overlaid onto corresponding multispectral image to remove spectral information coinciding with crop fields. With the crop fields masked out, each image was classified using Maximum Likelihood classifier to produce LC maps. In the masking procedure, majority of the crop fields that represent certain contrast with their adjacent areas (e.g. crop vs. fallow fields) were identified on the basis of their albedo, shape and size. The rest of the crop fields, those have smaller patch size with less contrast to their surroundings were left to the next step for identification.

Supervised image classifications were applied to the 1989, 2000 and 2004 images using Maximum Likelihood decision rule. The number of pixels in the training dataset for 1989 classification was 17,405. The numbers of training pixels for classifications of the 2000 and 2004 ASTER images were 30,066 and 28,461, respectively.

During the supervised classification 21, 19 and 18 different LC classes were defined for 1989, 2000 and 2004 images according to spectral variations in the scenes. Prior to labeling, the classes that represent variations of the same LC category (e.g. forest areas with varying canopy cover) were merged in order to reduce the number of classes. The classification procedure resulted with LC maps and statistics for three different dates. The LC maps that show spatial distribution of nine LC classes for 1989, 2000 and 2004 were given in Fig. 5 and the area coverage of the LC categories were summarized in Table 2.

Table 2 represents increase in the coverage of built-up and forest areas, while it shows a decline in grasslands. Fluctuations in the water coverage can be attributed to seasonal variations in the amount of water existed in the dam reservoir. The significant difference in the coverage of water between 1989 and 2000 is the result of the construction of the Sir dam reservoir that started collecting water in the beginning of 1990s. The urban area doubled during the 15-year period between 1989 and 2004.

Comparison of total coverage may not always provide the most efficient analysis of changes. Instead of taking area coverage of each LC category at each date into account, pixel-based comparison was used to produce change information on pixel basis and, thus, interpret the changes more efficiently taking the advantage of "-from, -to" information.

Classified image pairs of consecutive years were compared using cross-tabulation in order to determine qualitative and quantitative aspects of the changes for the periods from 1989 to 2000 and from 2000 to 2004. One of the important considerations during pixel-based comparison is to have image pairs of the same spatial resolution. Thus, the 2000 ASTER classification was resampled to 30 m resolution in order to make pixel-based comparison of Landsat TM (1989) and ASTER (2000) images possible for detecting changes in the first period (Table 3). Spatial resolution for the comparison of 2000 and 2004 classifications was 15 m (Table 4).

As can be seen from the Tables 3 and 4, area coverage of a particular LC class for a year (e.g. 2000) represented very small differences (e.g., forest coverage in 2000 appears to be 4,940.51 in Table 3, and 4,939.72 in Table 4). This phenomenon resulted from resampling of the 2000 ASTER image to 30 m for the first period, and from the fact that different spatial resolutions were used for calculating statistics in the first and second periods.

LC changes between 1989 and 2000

Cross tabulation is a means to determine amounts of conversions from a particular LC to the other LC categories at later date. Cross-tabulation of the 1989 and 2000 classifications clearly depicted large amounts of conversions mainly from agriculture, vegetated stream beds and grasslands. Table 3 represents quantities of conversions from earlier to later date. As can be seen from the Table 3, no conversions from water detected due to absence of the dam reservoir at the early date (1989). Narrow and temporary water surfaces such as creeks and seasonal streams were not considered as water bodies at the

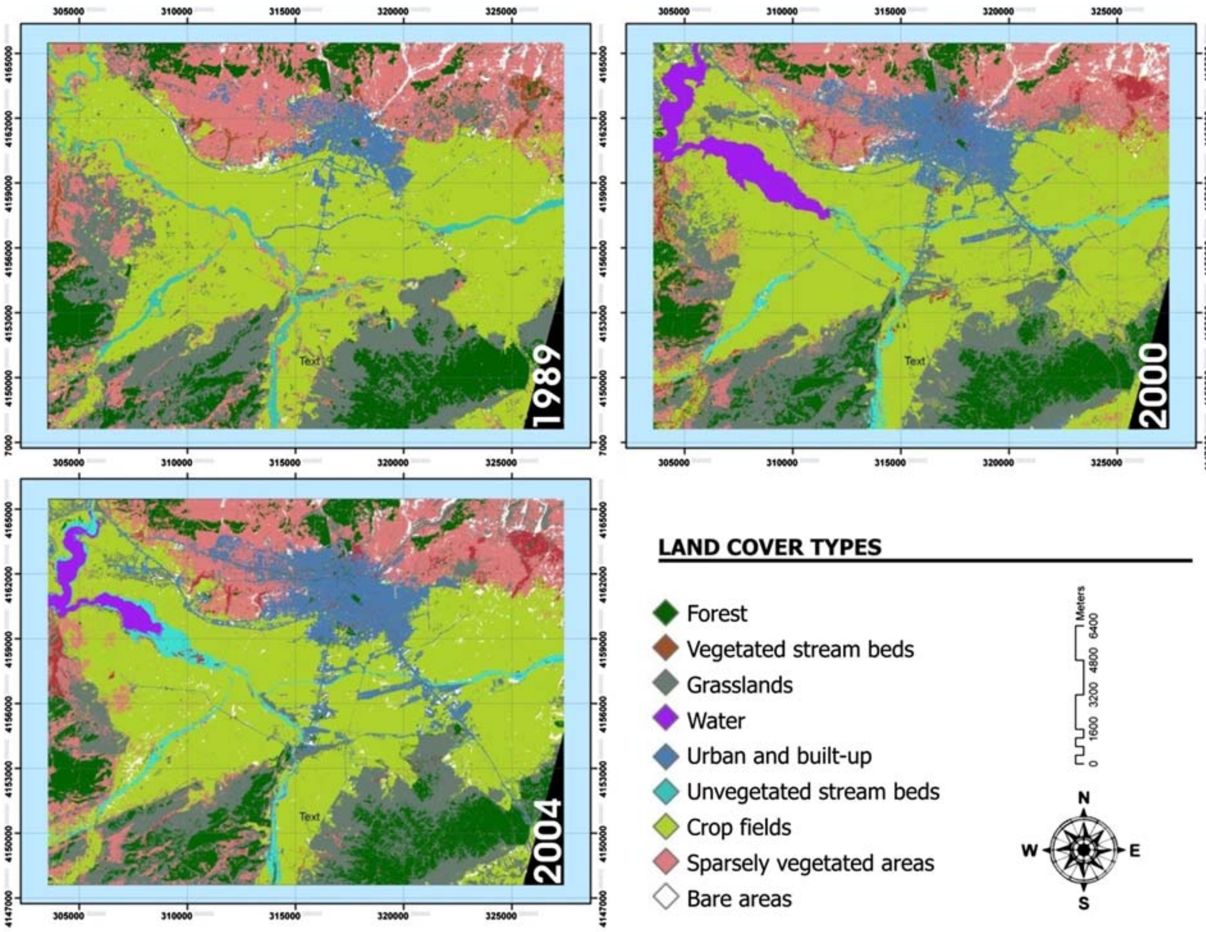

Fig. 5 Spatial distribution of LC at three different dates, 1989, 2000 and 2004

early date. Instead, these areas were classified as unvegetated stream beds. Between 1989 and 2000 a total of 1,276.86 ha of land converted to water due to dam construction.

Table 2 Area coverages of the LC categories

LC Types	Area (ha)		
	1989	2000	2004
Forest	4,960.33	4,939.72	5,143.12
Vegetated stream beds	407.83	645.46	698.51
Grassland	7,842.76	5,598.7	5,442.37
Water bodies	0.00	1,276.67	637.25
Urban and built-up	1,571.78	2,920.03	3,526.38
Unvegetated stream beds	949.52	485.3	1,059.86
Crop fields	17,137.26	18,073.71	18,306.05
Sparsely vegetated areas	7,854.78	6,882.28	5,822.53
Bare areas	1,201.16	1,103.56	1,289.36
Total	41,925.42	41,925.42	41,925.42

Land-to-water conversions may have profound impacts on ecosystems such as irreversible losses of wildlife habitats (e.g., Lind et al. 1996). In the case of K. Maraş, this process took place at the expense of agricultural ecosystems. The amount of conversion from agriculture areas to water occurred as large as 927.67 ha, 73% of the total land-to-water conversion.

The sparsely vegetated areas lie at the north of the city of K.Maraş and the south of the plain, which confines the city in the south. Conversions to agriculture were mainly occurred from grasslands and sparsely vegetated areas as large as 1,314.95 and 1,325.84 ha, respectively. This is an indicator of agricultural expansion over the semi-natural areas in the region.

Urban expansion led to one of the most dramatic LC changes in the region. Table 3 shows magnitude of the urbanization between 1989 and 2000. In cross tabulation, difference between row and column totals of a particular LC type yields the amount of positive

Table 3 LC conversions between 1989 and 2000

		2000 (ha)									
		For	VSb	Gra	Wtr	Urb	USb	CrF	SVg	Bar	1989
1989 (ha)	For	4,395.73	68.07	147.18	1.79	22.42	0.49	163.02	159.20	2.44	4,960.33
	VSb	15.03	248.47	13.08	2.11	23.39	0.16	57.43	45.32	2.84	407.83
	Gra	212.16	51.90	5120.34	31.92	232.71	19.17	1,314.95	831.42	28.19	7,842.76
	Wtr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Urb	3.17	8.53	6.58	0.41	1,476.35	5.20	41.75	2.76	27.05	1,571.78
	USb	3.82	7.15	120.54	191.69	3.41	392.97	212.00	15.27	2.68	949.52
	CrF	23.07	118.51	45.00	927.67	668.48	47.27	14,758.34	483.61	65.30	17,137.26
	SVg	282.74	138.08	107.30	116.31	411.40	16.98	1,325.84	5,166.48	289.65	7,854.78
	Bar	4.79	4.63	37.93	4.95	81.63	2.84	201.03	177.56	685.78	1,201.16
	2000	4,940.51	645.33	5,597.95	1,276.86	2,919.80	485.08	18,074.35	6,881.63	1,103.93	41,925.42

For Forest areas, *VSb* vegetated stream beds, *Gra* grassland, *Wtr* water bodies, *Urb* urban and built-up, *USb* unvegetated stream beds, *CrF* crop fields, *SVg* sparsely vegetated areas, *Bar* bare areas

or negative change between two dates. According to Table 3, the amount of urbanized area was calculated as 1,443.45 ha, nearly as large as the coverage of urban area at the early date (1989). Investigating the components of this conversion, the agriculture areas were found to account for 46% (668.48 ha) of the total space consumed by urbanization in this period. The major LC change that the 1989–2000 period witnessed can be considered as the losses of agriculture areas due to dam construction and urbanization.

LC changes between 2000 and 2004

LC changes in this period were analyzed using the same post-classification methodology as in the previous period. Cross tabulation of the statistics from 2000 and 2004 classifications were given in the Table 4. Post classification comparison showed that the urban coverage increased 606.35 ha from 2920 to 3526 ha.

One of the important considerations for evaluating urbanization and its impacts is to properly define the boundaries of “urban and built-up” class. As it was indicated in the classification scheme (Table 1), this category included not only the large building islands, but also other sealed surfaces such as concrete or asphalt roads, parking lots, city squares and other paved areas.

The conversion between water and unvegetated stream beds was calculated to be 494.71 ha. This conversion can be interpreted as a result of seasonal decrease in the water level of the reservoir. These

Table 4 LC conversions between 2000 and 2004

		2004 (ha)									
		For	VSb	Gra	Wtr	Urb	USb	CrF	SVg	Bar	2000
2000 (ha)	For	4,766.24	29.45	50.31	0.81	2.34	3.38	32.27	54.45	0.47	4,939.72
	VSb	40.10	255.17	48.06	0.56	49.48	6.17	134.57	106.54	4.82	645.46
	Gra	50.15	33.68	4,882.16	2.86	179.93	33.10	231.86	144.36	40.59	5,598.70
	Wtr	1.04	32.00	24.28	610.02	0.72	494.71	105.64	7.81	0.47	1,276.67
	Urb	11.99	26.39	44.17	12.26	2,731.16	10.06	30.44	24.53	29.03	2,920.03
	USb	2.32	1.28	15.62	3.94	25.29	364.25	32.63	13.93	26.06	485.30
	CrF	139.37	105.77	132.75	5.11	290.25	134.30	16,604.24	435.06	226.87	18,073.71
	SVg	130.97	210.80	129.96	1.60	184.46	11.00	1,075.79	4,971.65	166.05	6,882.28
	Bar	0.95	3.96	115.07	0.09	62.75	2.90	58.61	64.22	795.02	1,103.56
	2004	5,143.12	698.51	5,442.37	637.25	3,526.38	1,059.86	18,306.05	5,822.53	1,289.36	41,925.42

For Forest areas, *VSb* vegetated stream beds, *Gra* grassland, *Wtr* water bodies, *Urb* urban and built-up, *USb* unvegetated stream beds, *CrF* crop fields, *SVg* sparsely vegetated areas, *Bar* bare areas temporarily flooded areas were included in the unvegetated stream beds.

Conversions to agriculture were also evident in this period. A total of 1,075.79 ha area changed between 2000 and 2004 from sparsely vegetated to agriculture areas. As previously mentioned, the “sparsely vegetated areas” include semi-natural areas, where low percent tree cover exist. This class also included olive groves. Large amounts of conversion from this class occurred as a result of removal of olive groves for opening agriculture fields.

Conclusion

LC mapping and change detection have increasingly been recognized as one of the most effective tools for environmental resource management. K.Maraş and its environs has an important potential for agriculture as a result of extensive and fertile alluvial soils. Besides its high potential for agriculture, the region has attracted various industries that have become more evident following the actions taken by the government aiming to support industries in the region. The region was declared as one of the priority development regions in Turkey in the end of 1960s. Promotion of industries has led to significant increases in the population, and thus fueled urbanization. Population of the city of K.Maraş increased from 228,129 to 326,198 between 1990 and 2000 (TSI 2004). Over 40% increase of the population in a 10-year period coincides with unprecedented development that the region witnessed.

Irrigation demands, increasingly met by growing capacity of the irrigation network and establishment of the dams played an important role in extension of agriculture areas and diversification of agricultural practices.

These processes can be considered as the major driving forces that determined LC changes. Four-year change detection that relied on ASTER images

Table 5 Proposed monitoring scheme for the K.Maraş region

Spatial scale	Change detection			Classification scheme	Areas of special Interest
	Data	Frequency	Image acquisition		
Landscapes (land use/ land cover)	ASTER	5 years	near-anniversary dates	1. Urban and built-up 2. Forest 3. Sparsely vegetated areas 4. Grassland 5. Vegetated stream beds 6. Unvegetated stream beds 7. Bare areas 8. Crop fields 9. Water bodies	1a. spatial context: low density built-up areas on the urban periphery that still represent semi-natural character with a network of roads and vegetated patches prone to urban expansion 1b. major concern: urban encroachment 2a. spatial context: Transition between agriculture and semi-natural areas 2b. major concern: Agricultural expansion
Urban territories	IKONOS Quickbird	2 years	Flexible (low- or no-cloud cover required)	1. Built-up and paved areas 2. Urban green spaces (parks) 3. Agriculture areas (crop fields, wineyards, orchards, greenhouses) 4. Semi-natural areas 5. Roads 6. Water bodies	1a. spatial context: transition between built-up and semi-natural and/or agriculture areas 1b. major concern: conservation of arable lands 2a. spatial context: Small and isolated patches of semi-natural areas in close vicinity of the urbanized area 2b. major concern: Maintenance and provision of urban green space

revealed significant changes very efficiently. This may be a basis for establishing a frequency for the monitoring program. Five-year frequency may be applied for the future environmental monitoring.

Given the complexity of the LC changes arising from major regional development strategies, an accurate landscape-level environmental monitoring strategy based on remote sensing and GIS may play a key role for management of the region's environmental resources. This may be accomplished by establishing a monitoring program that relies on remote sensing and GIS. Principal components of short- and mid-term environmental monitoring scheme aiming to combine optimum data type, seasonality, classification scheme and special areas of interest for least negative impacts on the environment was given in the Table 5.

Medium resolution satellite images such as Landsat and SPOT have extensively been used for monitoring land use and LC from local to regional scales (e.g. Alphan 2003; Esbah 2007; Kepner et al. 2000). However, availability of contemporary data and its cost plays a major role in data selection.

Malfunction of the ETM+ sensor onboard the Landsat 7 platform that leads to images with small regular gaps in the data due to the Scan Line Corrector (SLC) and relatively high acquisition costs of the SPOT and Landsat TM (e.g. Landsat 5), makes it compulsory to use alternative datasets for determining current state of LC in an area of interest. ASTER imagery was considered as an ideal data source for landscape-level environmental monitoring for the region, given its relatively higher spatial resolution (15 m in visible and near-infrared regions) and reasonable cost.

Crop fields, sparsely vegetated areas and grasslands are the most prevailing LC types in the region. These LC types show high seasonal variation due to vegetation phenology. Thus, seasonal consistency of the images involved in change detection can have a positive impact in reducing change detection errors.

Landscape-level environmental monitoring needs areas of special interest, determined by the magnitude and extent of the observed LC changes. These areas of special interest may be subject to more detailed change detection at finer spatial and time scales. Taking the urbanization and agricultural expansion phenomena into consideration, urban fringe, where built-up areas interact with other LC types and the transition between crop fields and semi-natural areas can be considered as special areas of interest for landscape-level monitoring in the region.

This study showed the use of satellite images with different spatial resolutions. The flexibility of the post-classification change detection methodology to use images of different spatial and spectral resolutions acquired by different sensors made a successful change analysis possible. Future studies may include high spatial resolution satellite images (e.g. Quickbird) in addition to multitemporal ASTER datasets in order to perform more detailed change analysis in respect to special areas of interest.

Acknowledgments The authors gratefully acknowledge the scientific research grant (TOVAG 104O161) of the Scientific and Technological Research Council of Turkey (TUBITAK).

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